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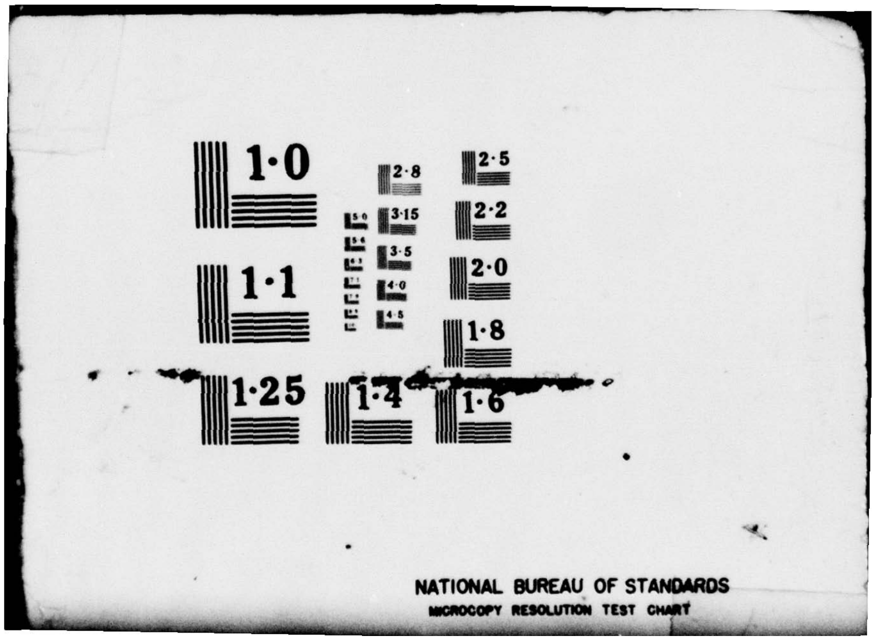
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Lockheed Report No. 21194

SONAR RANGE PREDICTION FEASIBILITY STUDY - FINAL REPORT (U)

CONTRACT NObsr 95258

New.

Submitted to:

U. S. NAVAL SHIP SYSTEMS COMMAND
DEPARTMENT OF THE NAVY
WASHINGTON, D. C.

21 DECEMBER 1967

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FOREWORD

(U) This study was performed by the Lockheed-California Company under Contract NObsr 95258 with the Naval Ship Systems Command. The purpose of the study was to determine the feasibility of designing a sonar range prediction system for the SQS-23 Sonar which gives a graphical, continuous profile of expected sonar range.

(U) The Lockheed-California Company wishes to thank Mr. John Cawley and his colleagues of the Arthur D. Little Co. who reviewed the original draft of this report at the request of the Naval Ship Systems Command and made many helpful suggestions. Many of their comments have been incorporated into this report.

(U) This report was prepared by R. M. Lesser. The critical review and helpful suggestions of Dr. A. J. Carsola and RADM L. D. Coates, USN (Ret.), are gratefully acknowledged.

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I - INTRODUCTION

(U) The fleet urgently needs rapid and accurate methods of converting bathythermograph observations to meaningful range predictions without requiring complicated interpretation. The expendable bathythermograph (XBT) provides the fleet with a valuable tool for collecting information on temperature structure without interfering with operations.

(U) Present sonar range prediction techniques, such as NavShips 900.196[1/] and TACRAPS[2/] are used, but they have the disadvantage of providing range predictions at two or three discrete depths only. The Fleet Numerical Weather Facility (FNWF) has significantly contributed to advancing the state-of-the-art in sonar range prediction utilizing high-speed digital computers and highly sophisticated prediction models[3/]. Model development has progressed greatly in the past few years through work at the Naval Undersea Warfare Center[4/,5/] and other installations. However, these models are not directly usable at sea because computers are required for implementation.

(U) The purpose of this study was to determine the feasibility of developing a sonar range prediction atlas applicable to the SQS-23 sonar which will provide continuous profiles of expected detection range as a function of sound velocity or temperature profile. This study included an evaluation of the effects of small changes in layer depth and sound velocity gradient on expected sonar range. Both normal mode and ray theory propagation models were utilized for comparison purposes in cases where a positive surface layer existed.

(U) Two existing temperature and sound velocity profile classification systems were studied to determine the feasibility of basing a range prediction atlas on one of these systems. The first, developed by the Naval Research Establishment in Halifax, Nova Scotia[6/] was based on temperature profiles, while the second, the FADAP classification system developed by FNWF (unpublished) was based on sound velocity profiles.

II - EFFECTS OF SOUND VELOCITY PROFILE CHANGES

GENERAL

(C) In order to determine the feasibility and utility of any range prediction system, it is necessary to determine the acoustic significance of changes in sound velocity profiles. In the case of a positive surface layer, both normal mode theory and ray theory can be utilized for computing propagation losses. For the purposes of this study, computations of propagation loss at 5 kc (corresponding to the SQS-23 Sonar) were made utilizing both normal mode theory and ray theory in the case of a positive gradient, and ray theory only for a negative gradient. A number of conditions representative of sound velocity profiles in the eastern North Pacific during all seasons of the year were chosen. Propagation losses were converted to expected detection range utilizing an average adjusted figure of merit (AFOM) for the SQS-23. The 80-db one-way propagation loss range, based on an average AFOM of 160 db was chosen as the expected range for this study. This is based on the convention that the single-ping 50% probability of detection range is that range at which the two-way propagation loss is equal to the AFOM. It is recognized that the average AFOM for the SQS-23 may vary widely. This fact will become important later in discussions of range prediction systems. However, for the purpose of examining the acoustic significance of sound velocity profile changes, utilization of an average AFOM will suffice.

GRADIENT CHANGES

(C) Table I summarizes the effects on range for a submarine at periscope depth of systematic changes in positive gradient in the layer for a 360-foot layer. The table depicts the results of normal mode theory and ray theory propagation loss computations. Figure 1 depicts the difference in expected range for near-isovelocity and isothermal gradients. Normal mode theory predicts that when the gradient in the layer is near-isovelocity, a gradient change of .002 sec^{-1} is significant. This implies that when a very weak positive gradient exists, an accuracy of $\pm$.002 sec^{-1} is necessary. With stronger gradients, however, such accuracy is definitely not required.

TABLE I

EFFECTS OF GRADIENT CHANGE IN THE SURFACE DUCT
FOR A 360-FOOT DUCT UTILIZING NORMAL MODE THEORY

GRADIENT (SEC^{-1})	RANGE (KYD)	ΔRANGE (KYD)	$\bar{R}$	$\frac{\Delta R}{\bar{R}}$, %
0	10.0			
		4.0	12.0	33.3
+.002	14.0			
		1.8	14.90	12.1
+.004	15.8*			
		1.2	16.40	7.3
+.006	17.0			
		0.9	17.45	5.6
+.008	17.9			
		0.9	18.35	4.4
+.010	18.8*			
		0.7	19.15	3.7
+.012	19.5			
		0.7	19.85	3.5
+.014	20.2			
		0.7	20.55	3.4
+.016	20.9*			
		0.6	21.20	2.8
+.018	21.5			

* Interpolated. Others computed

Ray theory and normal mode theory agree on this point. It should be noted, however, that there is substantial disagreement between the two theories in their range predictions. Experimental propagation loss data [7] have indicated that normal mode theory is somewhat optimistic, while ray theory appears pessimistic. This still must be checked with further experimental evidence. Vitro Laboratories [8, 9] performed a systematic parametric study of the effects of gradient changes on predicted range for the SQS-23. The Vitro values for a 400-foot duct are presented for comparison purposes in Table II, along with the ray theory calculations performed by Lockheed for a 360-foot duct. It can be seen that agreement is good. The major difference occurs in the case of the isovelocity gradient. However, this difference is not significant.

(C) Figure 2 presents theoretical propagation loss with range at periscope depth and at 500 feet for the two cases illustrated in figure 1, utilizing normal mode theory. The losses at periscope depth average 5 to 10 db lower for the isothermal case than for the isovelocity case. This can probably be attributed to greater leakage out of the duct in the isovelocity case. With a strong surface duct the energy will be

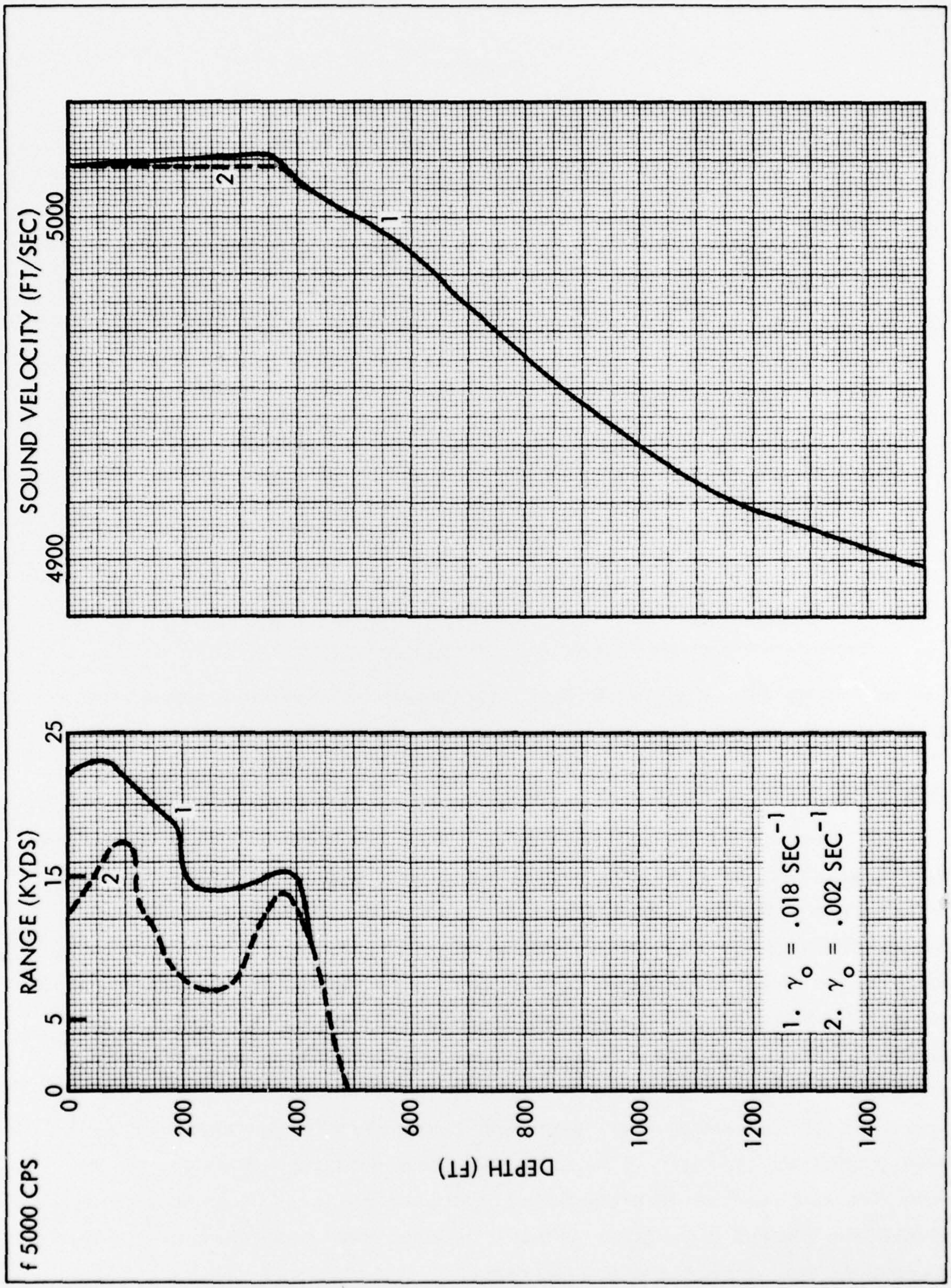

Figure 1 - Effects of Layer Gradient on Expected Range - Deep Duct

TABLE II
COMPARISON OF VITRO CORP. COMPUTATIONS FOR A 400-FOOT DUCT AND LOCKHEED COMPUTATIONS FOR A 360-FOOT DUCT UTILIZING RAY THEORY

GRADIENT (SEC^{-1})	VITRO RANGE, KYD	LOCKHEED RANGE, KYD
0	9	8.6
.002	9	8.7
.006	9	8.7
.008	9	8.7
.010	9	8.7
.012	9	8.7
.014	9	8.7
.016	9	8.7
.018	9	8.7

"trapped" in the duct, resulting in very little leakage. The opposite will be true for the isovelocity case.

CHANGE IN DUCT DEPTH

(C) Figure 3 depicts a comparison between a 360-foot and 470-foot duct where the duct gradients are equal. The normal mode theoretical model predicts that down to the portion of the layer where the maximum range is achieved (about 100 feet), there is an insignificant difference between the predicted ranges. Below that point, however, the deeper layer causes the energy to be spread out over a greater vertical extent. The two range profiles approximately parallel one another, merging below the layer. The increased layer depth causes significant differences (>10%) in the lower half of the layer, but not in the upper half. Therefore, in the case of the deep layer (300 feet and deeper), layer depth changes of ≥25% are significant for range prediction, especially in the deeper portion of the layer. However, for the most part, this effect on the prediction of expected range is not as great as the effect of change in gradient in the layer, in that it does not affect range significantly when the gradient approaches the isothermal case.

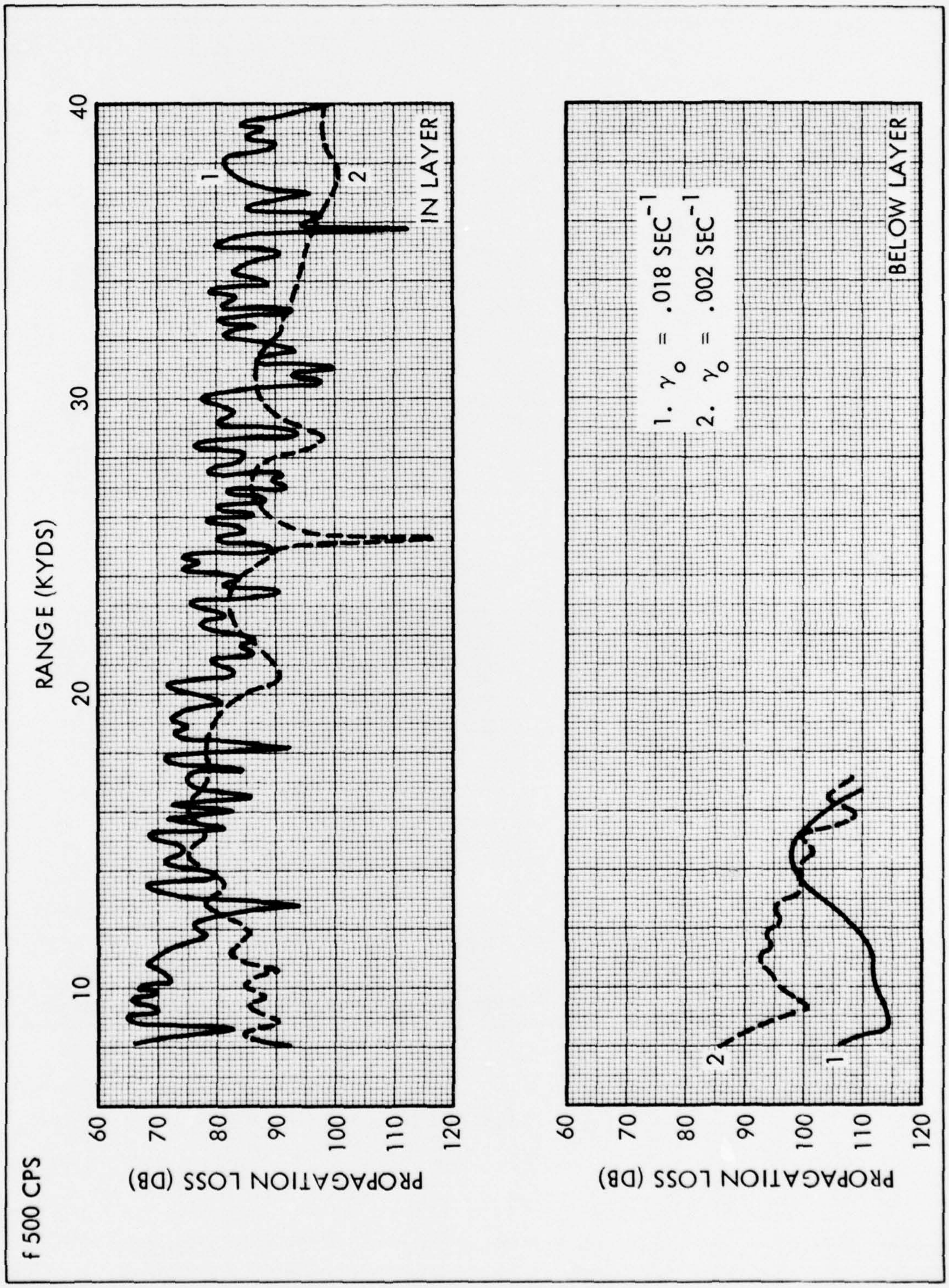

Figure 2 - Effect of Gradient Change on Propagation Loss

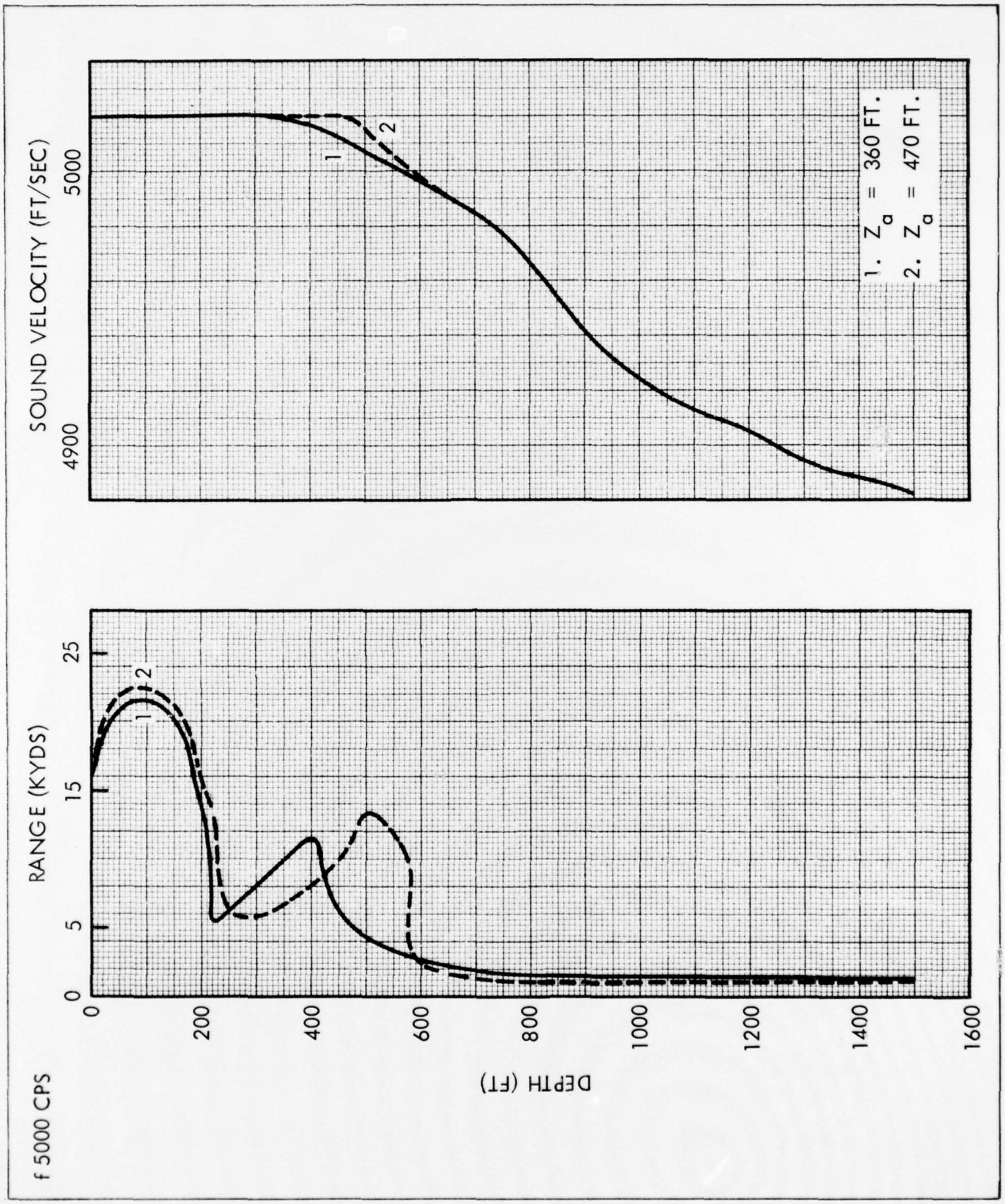

Figure 3 - Effects of Layer Depth on Expected Range - Deep Duct

COMBINED EFFECTS

(C) Figures 4 and 5 depict combined effects of duct gradient and layer depth changes on predicted range. It should be noted here that, in general, as the layer deepens, the gradient diminishes. The effects of these changes tend to counteract one another - the deeper the layer the longer the range, and the weaker the gradient the shorter the range. This is demonstrated in Figure 4, where the predicted range close to the surface is about 3 kyd longer for the isovelocity gradient than for the weaker gradient. However, this band of greater range extends over a depth of less than 50 feet. In the lower half of the layer the range curves predict nearly identical ranges, except in the bottom 30 feet or so where the effect of depth difference dominates.

(C) In Figure 5, Case 1 depicts a positive temperature gradient in the surface layer with negative gradients below the layer. Case 2 depicts an isovelocity layer overlying a subsurface duct. In this case, the positive gradient produces significantly higher ranges in the upper 100 feet, but the predicted range decreases rapidly with depth. In Case 2, lower ranges are predicted near the surface, but longer ranges are predicted below the layer because of the trapping of energy in the depressed sound channel.

DISCUSSION

(C) The foregoing presents typical cases showing the effects of sound velocity gradient and layer depth changes on expected sonar range. While the sample is too small to draw definitive conclusions, the indications are that a 20 - 25% change in layer depth will not affect a periscope depth range so long as the velocity gradient remains constant. Since, as stated earlier, the gradient in a duct tends to weaken as the layer depth increases due to incomplete mixing, the effects of gradient and layer depth change tend to balance each other. This points out a disadvantage of a parametric study where only one parameter is varied. A more detailed study where both layer depth and gradient are varied systematically in a realistic manner is required. In addition, controlled operational data is required to compare theoretical computations with operational performance.

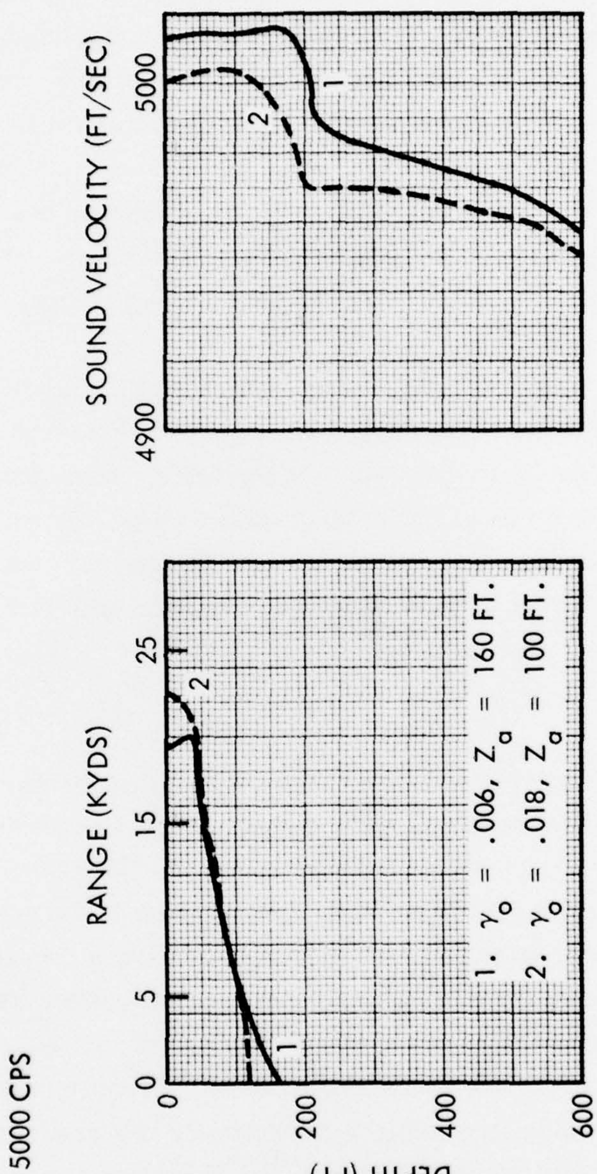

Figure 4 - Combined Effects of Layer Depth and Gradient Changes - Shallow Duct

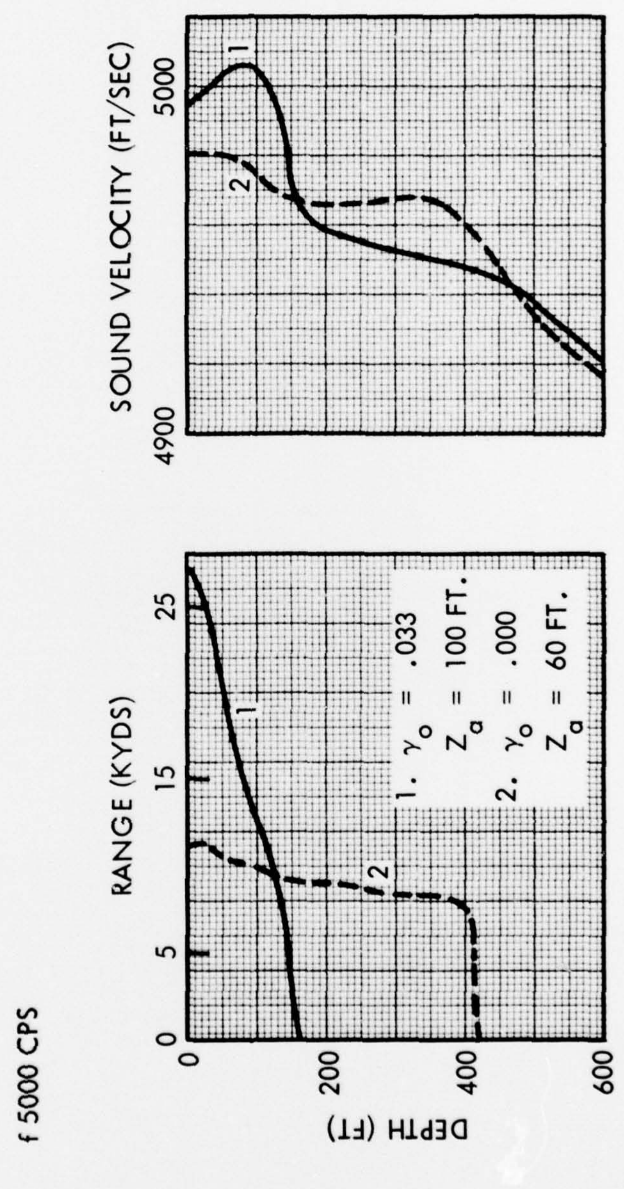

Figure 5 - Combined Effects of Surface and Subsurface Layer Depth and Gradient Changes - Shallow Duct

III - SOUND VELOCITY PROFILE CLASSIFICATION

GENERAL

(U) Several attempts have been made to classify temperature and sound velocity profiles in terms of types. The Naval Research Establishment of Canada has developed a system of twelve types of bathythermograph profiles[6]. This classification system was used to develop an SQS-4 sonar atlas for the North Atlantic Ocean[8]. As far as is known, however, no further work has been done with the NRE BT classification system. The Fleet Numerical Weather Facility has developed a classification system with ten types, each type having ten modification numbers. The system developed by FNWF is the one developed for FADAP (Fleet Antisubmarine Warfare Data Analysis Program).

NAVAL RESEARCH ESTABLISHMENT SYSTEM

(U) The Naval Research Establishment system has been designed for computer processing and is based on twelve basic BT types. These take into account gross variations in layer depth and in gradient in and below the layer. Thermal gradients are divided into six categories, ranging from strong positive through zero to strong negative. A positive gradient of >1 degree per 100 feet is considered strong and the weak positive ranges from 1 to 0.3+ degree per 100 feet. The zero gradient is considered to lie between 0.3 and -1 degree per 100 feet. The dividing lines among weak negative, moderate negative, and strong negative are -1, -2, and -4 degrees per 100 feet, respectively.

(U) The Ordnance Research Laboratory utilized the NRE system in checking the classification frequency by season of the twelve types. A total of 101,409 bathythermograph records from the ASWEPS area of the North Atlantic were used. It was found that all except 19, or 0.02%, of the BT's fit one of the twelve classifications. As a result of this ORL study, the NRE classification system appears to be highly satisfactory for summarizing oceanographic parameters related to sonar performance.

However, indications are that it may be too gross to utilize in a meaningful sonar range prediction system which would be a significant improvement over present techniques.

FADAP SYSTEM

(U) The FADAP system, developed by the Fleet Numerical Weather Facility, is based on ten sound velocity profile types, each with ten modification numbers. The FADAP system does not make any distinction concerning gradient in the positive layer. All positive gradients are treated as isothermal in the basic classification (number zero). The layer depths are divided into four categories, <50 feet, >50 but <150, ≥ 150 but ≤ 250, and >250 feet. According to normal mode theory predictions, these layer depth increments may be too gross. As far as can be determined, there are no statistics available which are comparable to the ORL statistics on the NRE system. Therefore, it is not possible to determine whether the FADAP system is representative.

IV - CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

(C) This feasibility study has been conducted to determine whether or not a sonar range prediction system for the SQS-23 sonar based on continuous "profiles" of expected range can be developed utilizing a relatively simple BT or Sound Velocity Profile classification system. In order to examine the effectiveness of the environmental classification system, it was necessary to study the acoustic significance of changes in sound velocity gradient and layer depth. The results of this study are inconclusive, because normal mode theory and ray theory predict significantly different results at 5 kc. Many sound propagation experimental results have indicated that in the presence of a surface duct, normal mode theory predicts propagation losses which are in better agreement with experimental data than does ray theory. However, these conclusions are based on research data, not on operational data. Very limited data from practical controlled fleet exercises are available for evaluation of sonar performance predictions. The question of which prediction models are more accurate under operational conditions cannot be resolved at this time.

(C) Normal mode theory predicts significant differences in expected sonar range for small changes in sound velocity gradient in a weak surface duct, while ray theory does not. In the case of an isothermal gradient, neither ray theory nor normal mode theory predict that small changes in gradient are significant. The XBT measures temperature gradients to an equivalent precision of $\pm .007$ sec^{-1}. This accuracy is probably sufficient in the case of negative sound velocity gradients or strongly positive sound velocity gradients. However, if the normal mode theory computations are correct for weak positive sound velocity gradients, the XBT does not provide sufficient accuracy.

(C) If normal mode theory is correct, the sound velocity and BT classification systems examined in this study do not adequately distinguish the strength of the surface duct to permit utilization of either system in a sonar range prediction system.

As a result of this, as well as the uncertainty of the existing propagation models under operational conditions, a new sonar range prediction system based on a BT or sound velocity classification system is not feasible at this time.

(U) This study has only been concerned with sound velocity and temperature profiles as they affect sonar range prediction. It has not considered other factors which may be of equal or greater importance. One of these is certainly the sea surface. Results of the Lockheed Deep Water Normal Mode Propagation Study [7] suggested strongly that this parameter is of great significance in sonar propagation. Unfortunately, sea surface roughness has largely been described in terms of "sea state", an empirical concept of little use in describing the environment. A useful sonar range prediction technique should consider the effect of the sea surface described in terms of energy spectrum, signficant height, slope spectrum, or some other observable, but physically significant characteristic. Further experimental work will be required before feasibility can be determined. Recommendations for further work are summarized below.

RECOMMENDATIONS

(U) 1. The question of the accuracy of sonar performance models can be answered through simple controlled fleet exercises which can be carried out with existing fleet systems and personnel. Such exercises should include some control of submarine tactics as well as surface ship tactics.

(U) 2. Operational sonar performance data should be provided to the Fleet Numerical Weather Facility, Naval Undersea Warfare Center, and other activities engaged in development of propagation and sonar performance models. These data will provide needed evaluation of the propagation models.

(U) 3. Since the fleet desires range predictions as a function of various probabilities, ranged from 10% to 90%, studies should be carried out to devise a method of presenting expected ranges with 10%, 25%, 50%, and 90% probabilities.

REFERENCES

1. Department of the Navy, Bureau of Ships, "Manual for Estimating Sonar Range (U)." U.S. NavShips Report 900.196, 16 March 1959 (Confidential).
2. U.S. Navy Fleet ASW School, San Diego, "TACRAPS - Tactical Range Prediction System (U)," 1966 (Confidential).
3. Fleet Numerical Weather Facility, "Synoptic Analyses and Prediction of Conditions and Processes in the Surface Layers of the Sea," FNWF Technical Note No. 28, March 1967.
4. Pedersen, M. A., D. F. Gordon, and A. J. Keith, "A New Ray Intensity Procedure for Underwater Sound Based on a Profile Consisting of Curvilinear Segments (U)," U. S. Navy Electronics Laboratory Report 1105, 30 March 1962 (Confidential).
5. Pedersen, M.A. and D. F. Gordon, "A Normal Mode Approach to Underwater Sound Propagation (U)," U. S. Navy Electronics Laboratory Report 1407, 27 September 1966 (Confidential).
6. Millar, F. Graham, "Machine Classification of Bathythermal Types," Naval Research Establishment of Canada Report 6013, May 1960.
7. "Normal Mode Propagation Study, Contract NObsr 93187. Volume II. Technical Report - Comparisons Between Theoretical and Experimental Results (U)," Lockheed-California Company Report 20556, 10 May 1967 (Confidential).
8. "Study to Determine the Governing Parameters and Quality of Data Inputs to ASWEPS (U)." Vitro Corporation Technical Report VL-2246-19-0, 3 August 1963 (Secret).
9. "Study to Determine the Governing Parameters and Quality of Data Inputs to ASWEPS (U)." Vitro Corporation Summary Report VL-2249-18-0, 30 August 1963 (Secret).

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2a. REPORT SECURITY CLASSIFICATION

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2b. GROUP

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3. REPORT TITLE

6 SONAR RANGE PREDICTION FEASIBILITY STUDY. / FINAL REPORT (U)

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

9 FINAL REPORT, 22 APR[redacted]966-[redacted]gh 21 DEC[redacted]967

5. AUTHOR(S) (Last name, first name, initial)

10 LESSER, ROBERT M. / Lesser

12 22p.

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
11 21 DEC[redacted]967	18	9

8a. CONTRACT OR GRANT NO.

15 NObsr-95258

b. PROJECT NO.

c.

d.

14 LR-21194

9a. ORIGINATOR'S REPORT NUMBER(S)

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13. ABSTRACT

This report presents the results of a study to determine the feasibility of a sonar range prediction system based on a graphical presentation of profiles of expected range. The effects of changes in gradient and layer depth on expected range were studied. Two BT classification systems were studied to determine their application to a range prediction system. Because of the gross features of the classification systems and the uncertainties of range prediction models, it is concluded that a range prediction system such as the type studied here is not feasible at this time.

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